The XMM Cluster Survey: Future constraints

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Clusters of Galaxies as Cosmic Laboratories
Stockholm, 13 September 2011

XCS

XMM Cluster Survey

- Complete *XMM-Newton* archive (serendipitous) >6000 observations, ~600 sq. deg.

- Science goals
  - Find galaxy clusters
  - **Constrain cosmology using galaxy clusters**
  - Study redshift evolution of cluster gas (scaling relations)
  - Study galaxy evolution in clusters
  - Study properties of unusual X-ray sources, e.g. high-redshift quasars and isolated neutron stars

- www.xcs-home.org

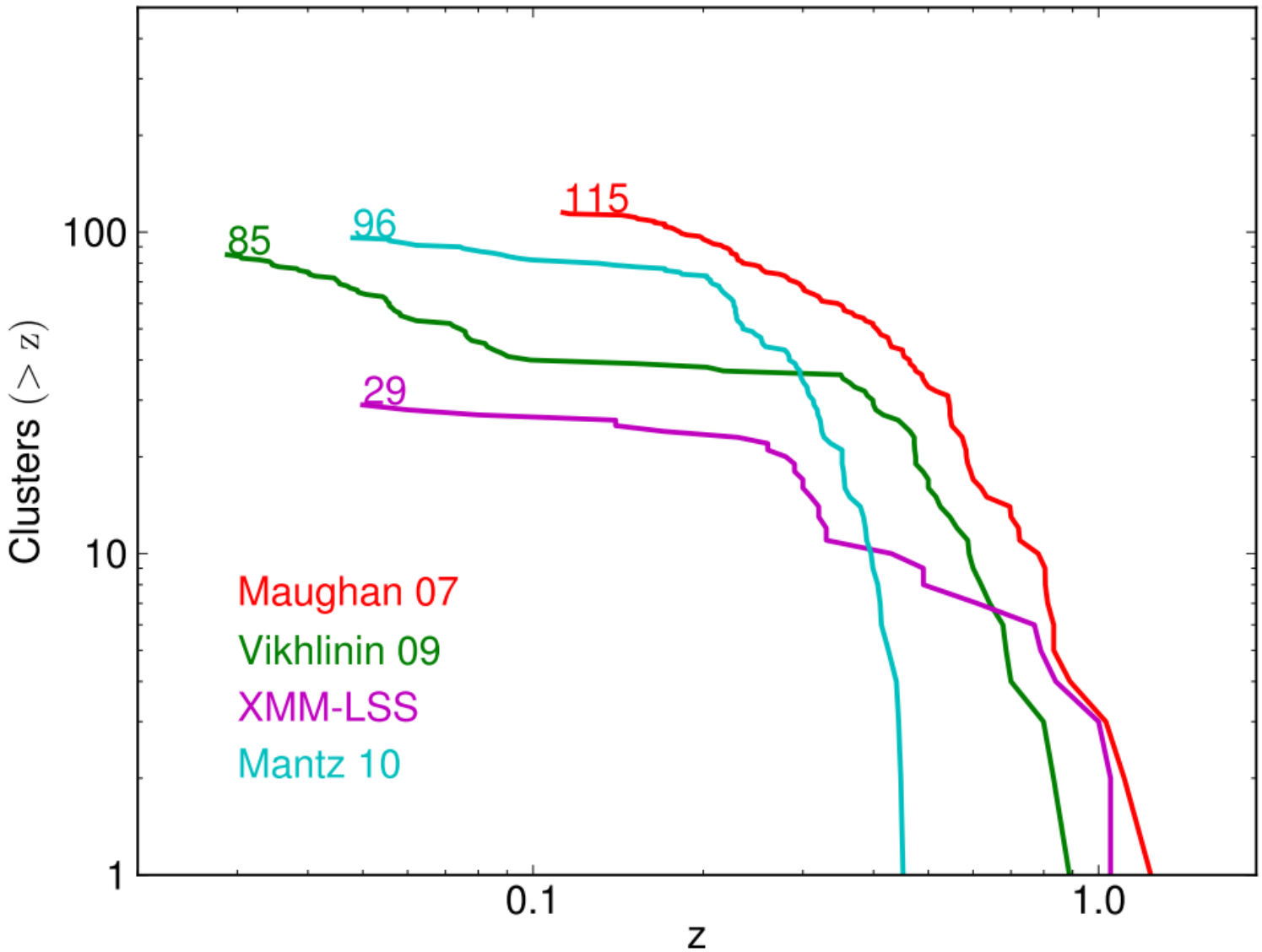
Cluster Finding

- X-ray temperature, flux, redshift, spatial parameters
  - Flux limit: ~5 x 10^{-14} erg s^{-1} cm^{-2}
  - z_{max} = 1.46 (so far)
  - Final area: ~500 sq. deg.

- Several thousand clusters expected
  (3675 extended-source candidates so far)

- Targeted pointings excluded for cosmology
  (but useful for mass calibration)

Current X-Ray Cluster Surveys



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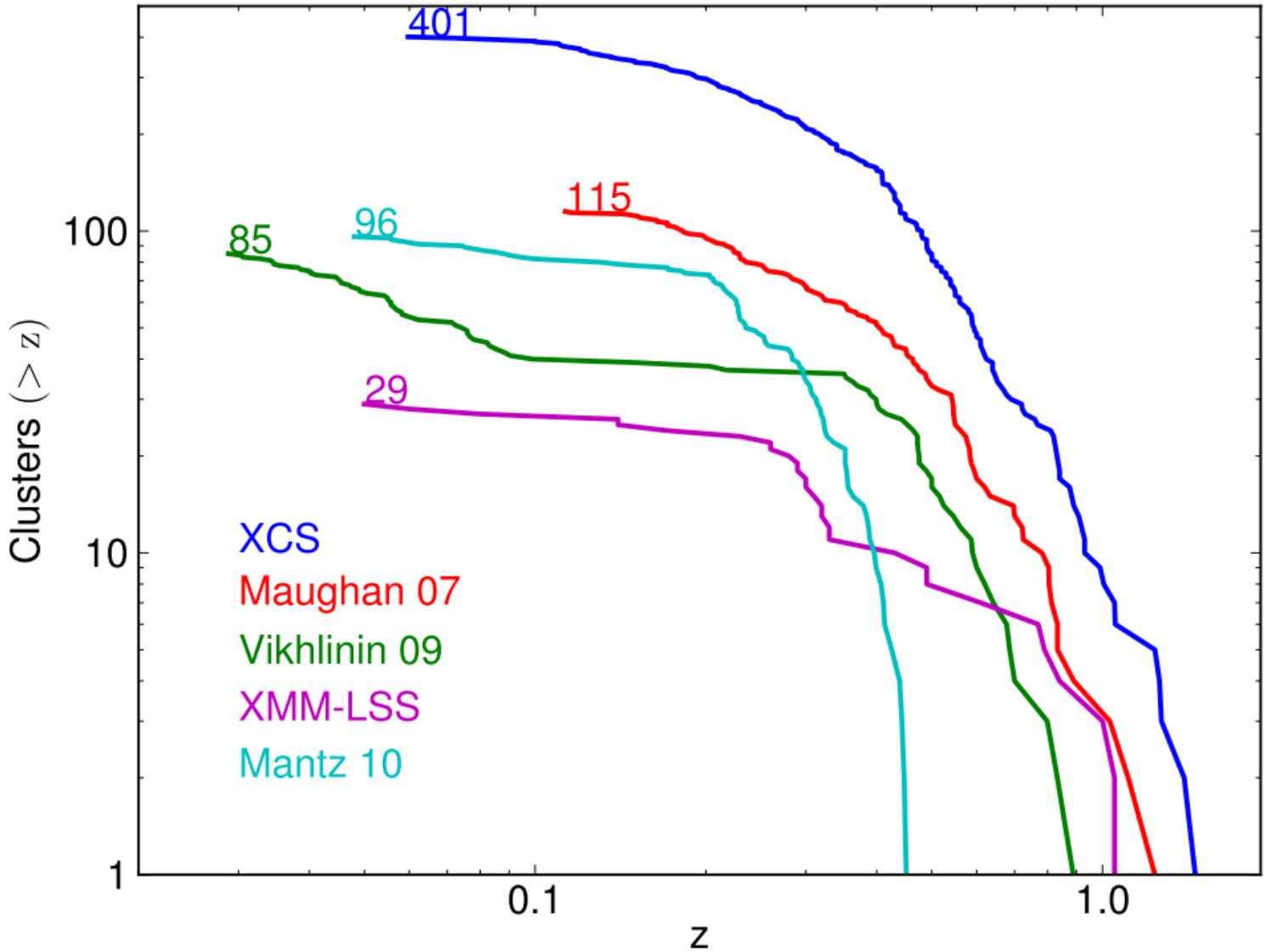
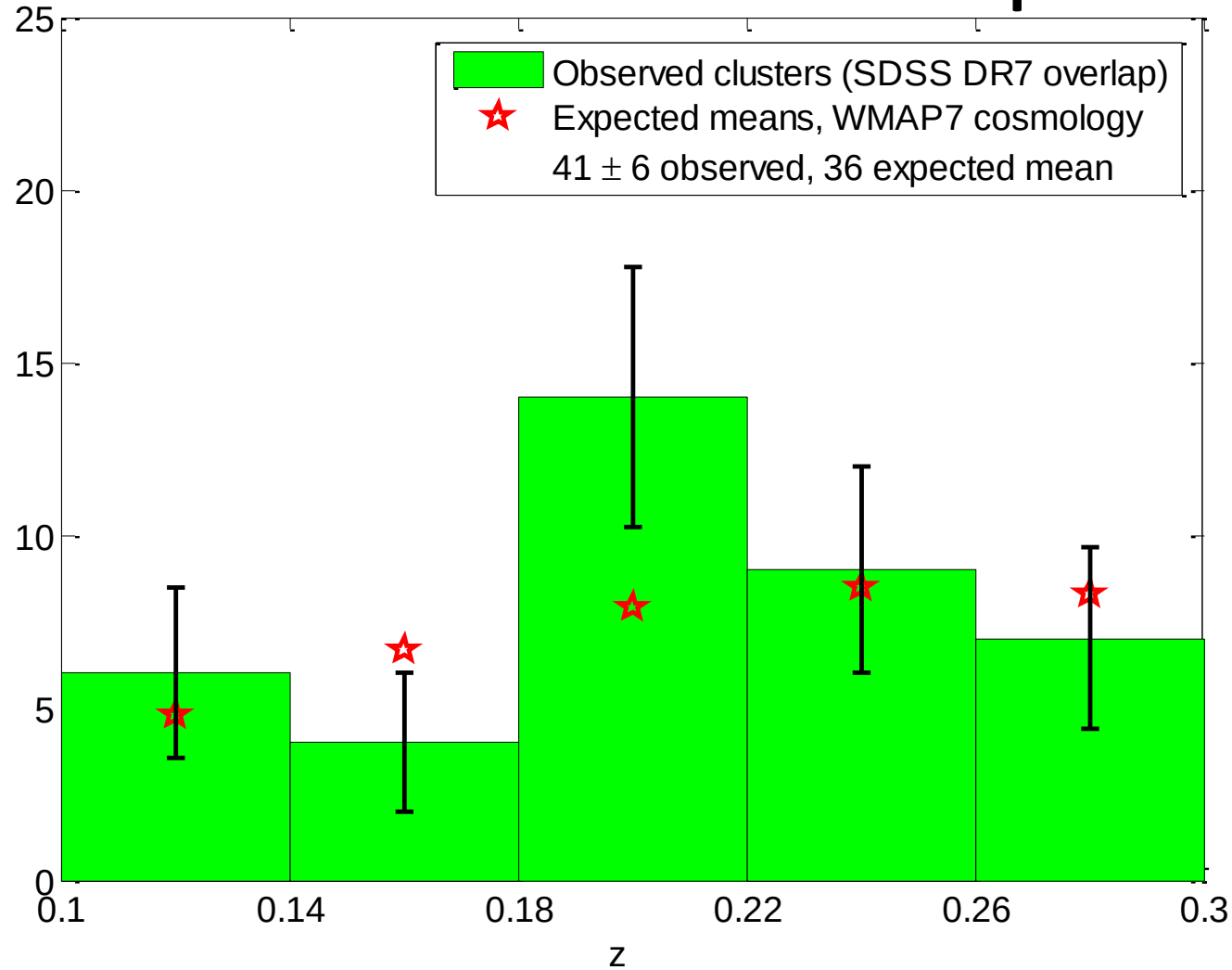


First comparison: SDSS DR7—XCS-DR1 overlap

$0.1 < z < 0.3$
$T > 2$ keV
>300 counts
121 sq. deg.

Measurement errors ignored



M.S. et al., in prep.

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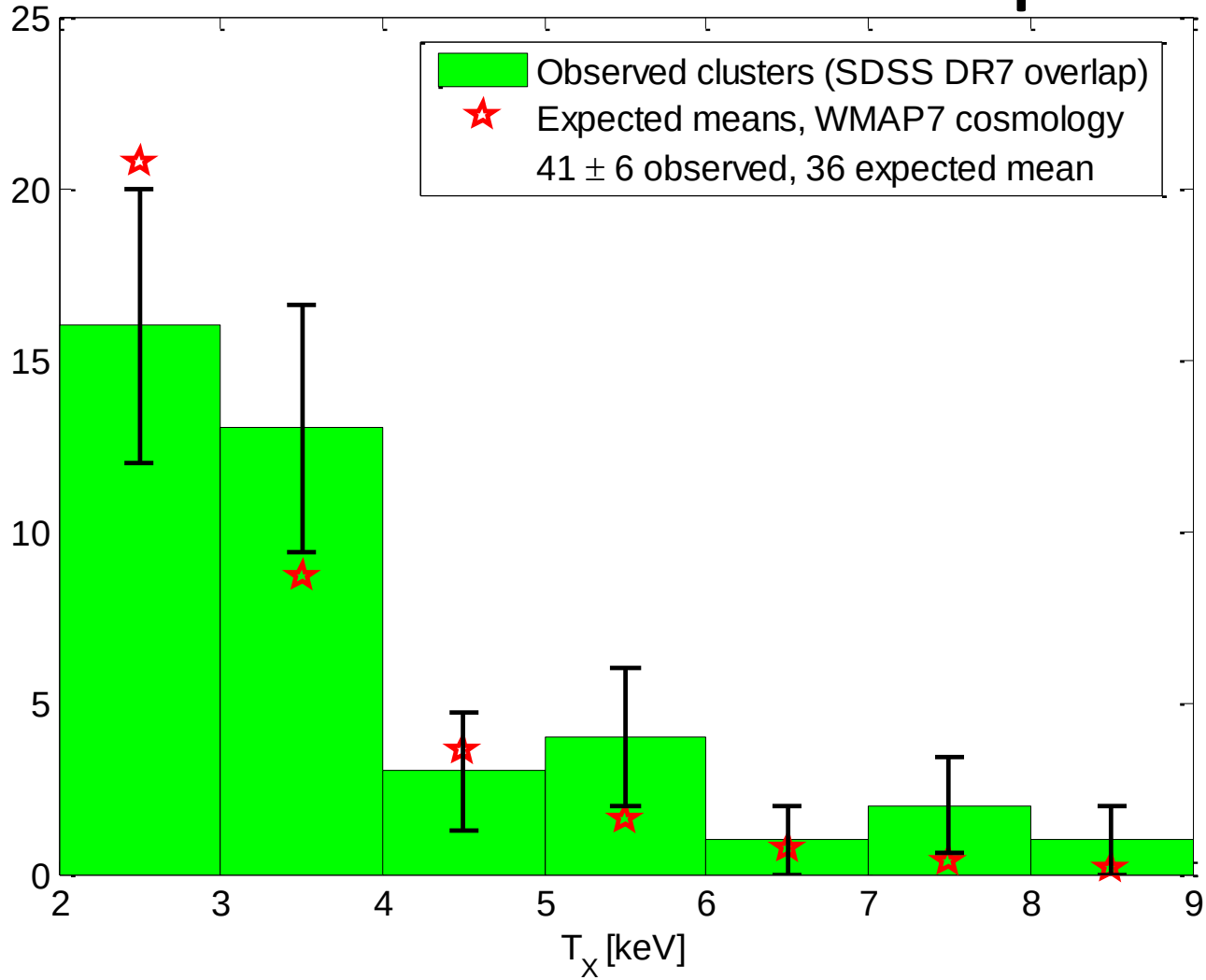
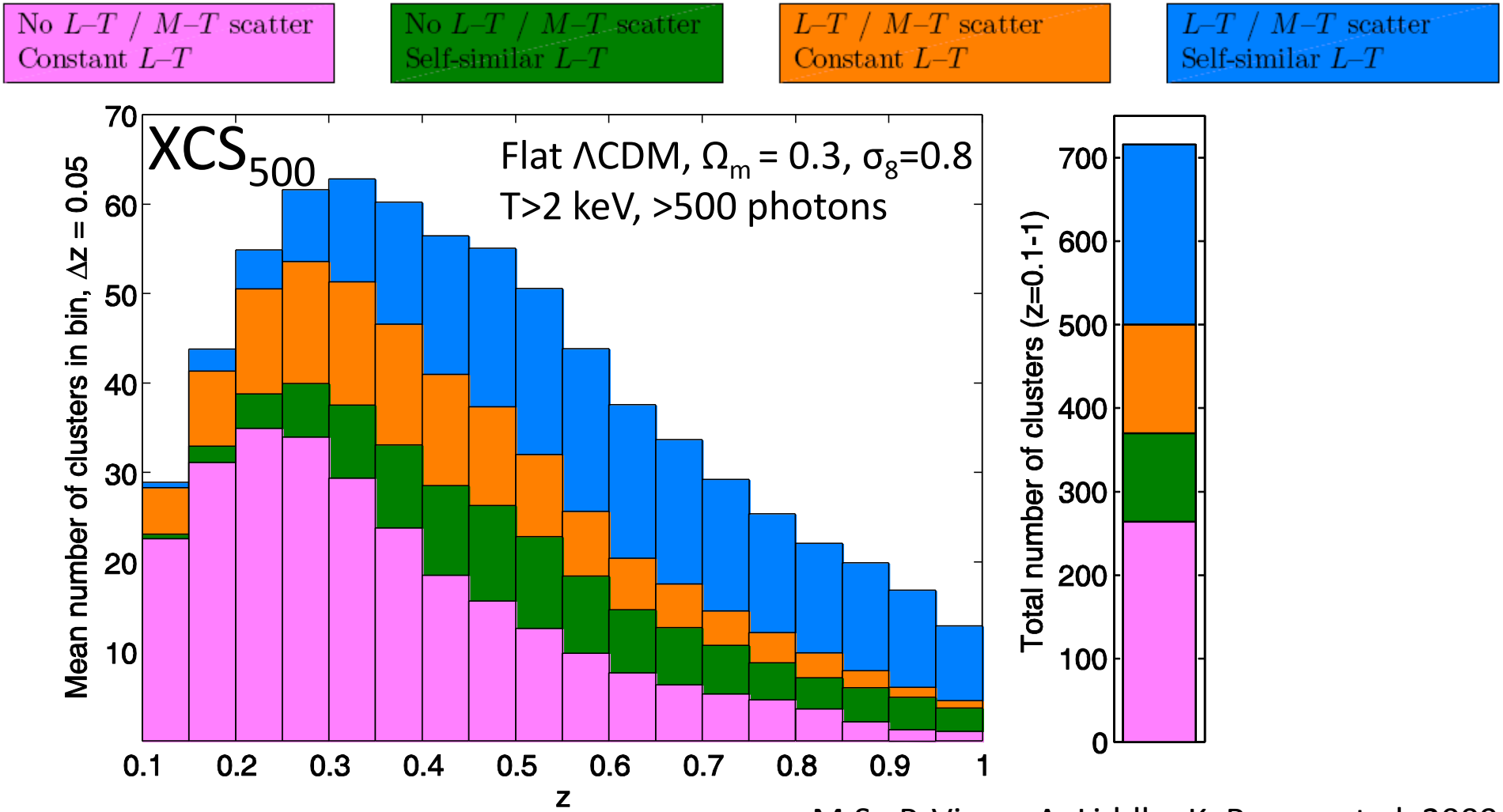


M.S. et al., in prep.

FORECASTS – WORK IN PROGRESS

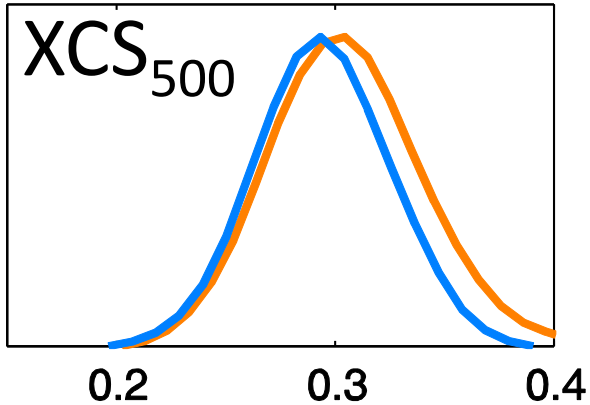
Predicted Detected Distributions



M.S., P. Viana, A. Liddle, K. Romer et al. 2009

This includes our simulated selection function, consistent treatment of scatter, etc.

Forecast Constraints
Self-Calibrated L-T Relation w/ Scatter

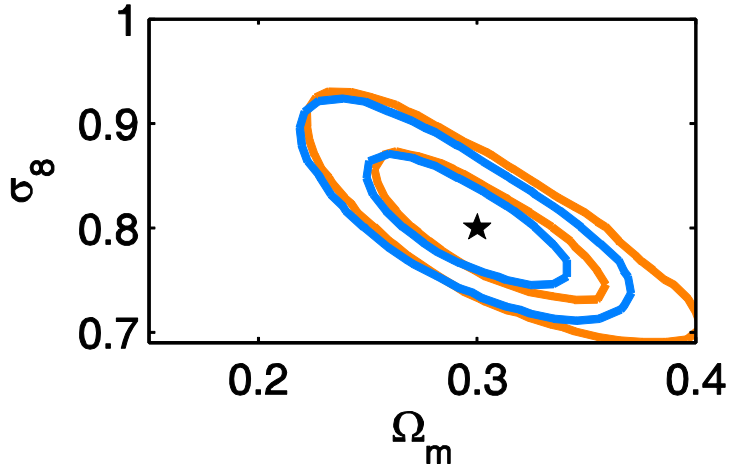


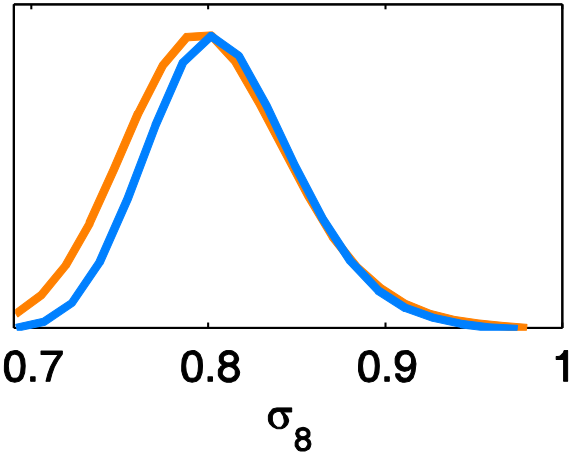
No L-T evolution
Self-similar L-T evolution

$\sigma(\Omega_m) < 0.03$

$\sigma(\sigma_8) < 0.05$

Note: not using flux measurements
Fixed M-T (HIFLUGCS), $0.1 < z < 1$
4 L-T parameters marginalized over

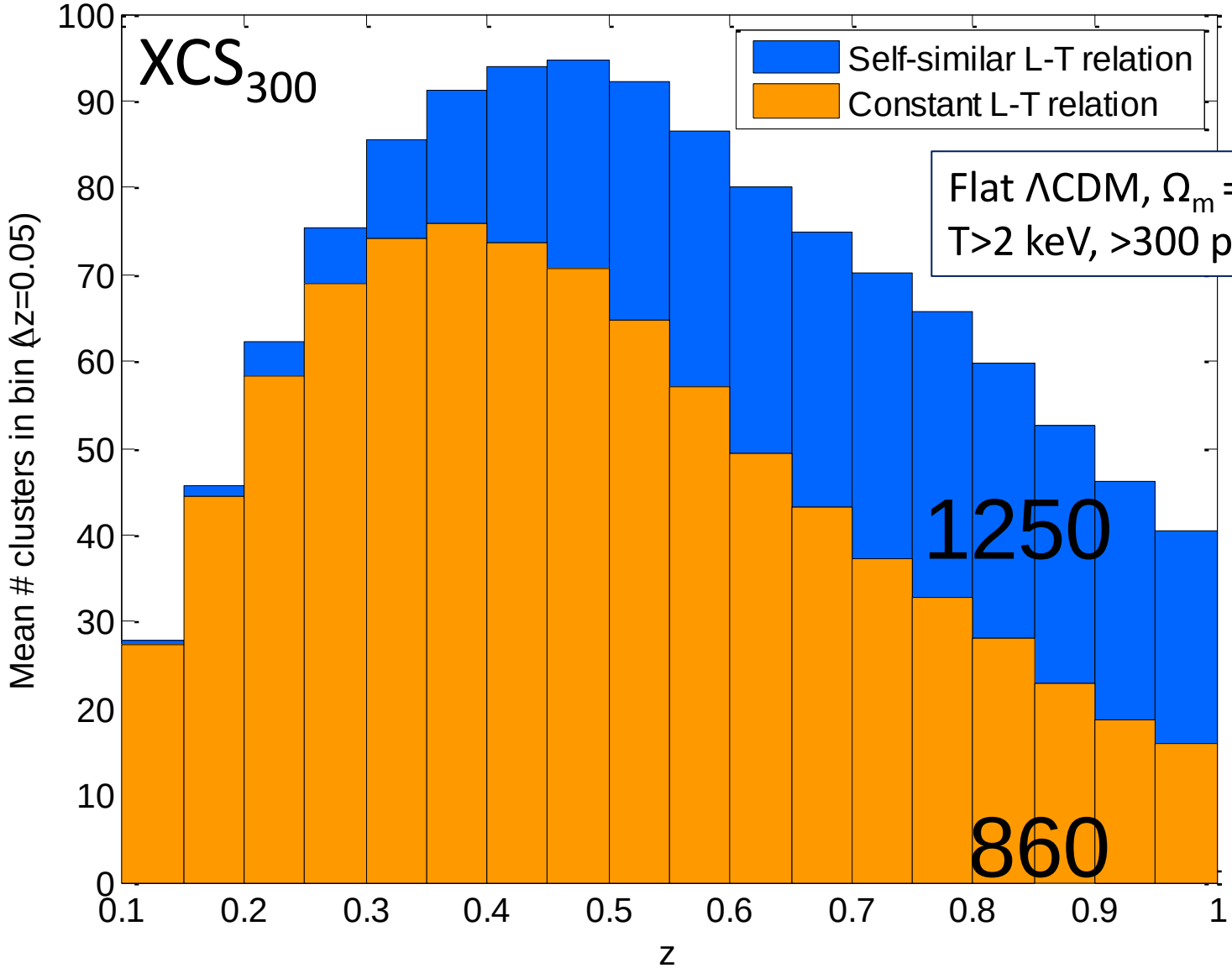




NB: Number counts only (serendipitous)

M.S., P. Viana, A. Liddle, K. Romer et al. 2009

Predicted Detected Distributions



~300 photons limit for small T (hence M) uncertainties

~3/4 increase in clusters by lowering the threshold

M.S. et al., in prep.

XCS_{300}

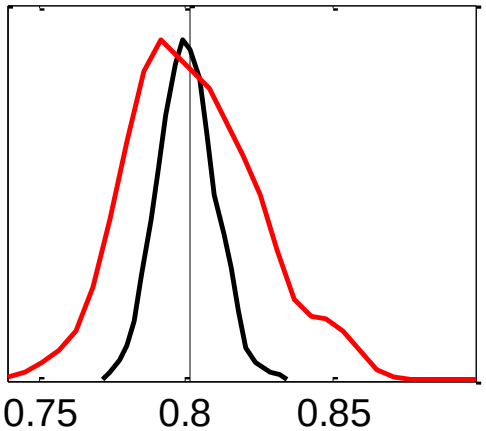
Forecast: ΛCDM

Fiducial model

$\Omega_M = 0.266$
$\Omega_b = 0.0449$
$h = 0.71$
$\sigma_8 = 0.801$
$n_S = 0.963$
$\sigma(\alpha_{M\text{-}T}) = 15\%$

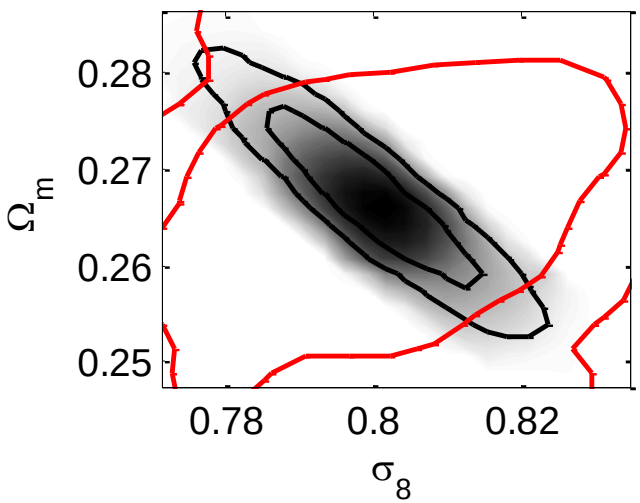
Varying

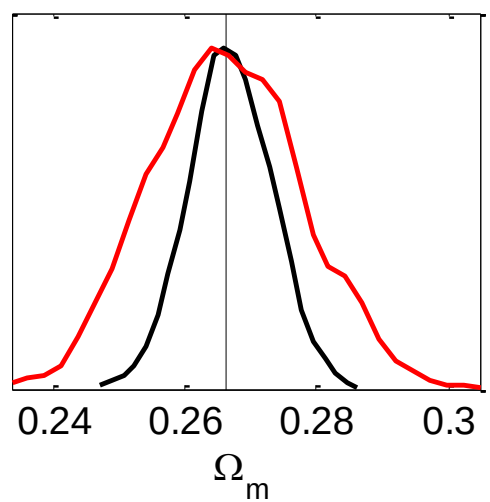
σ_8 Ω_M $\alpha_{M\text{-}T}$



$\sigma_8 = 0.80 \pm 0.01$, ± 0.02

$\Omega_M = 0.266 \pm 0.005$, ± 0.010





$\alpha_{M\text{-}T}$ is the normalization of the mass—temperature (M—T) relation, here used to illustrate many possible mass-calibration uncertainties

M.S. et al., in prep.

Comparison to Current Results

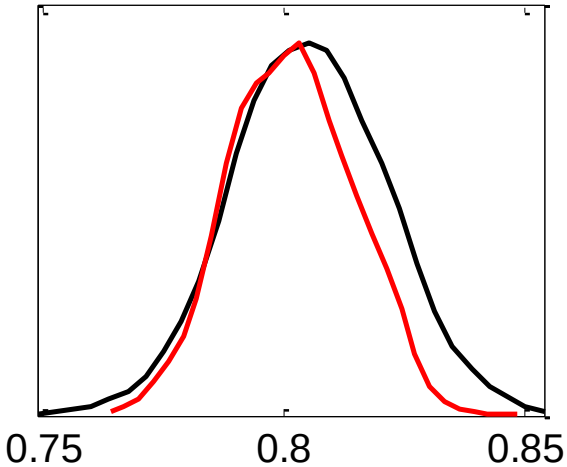
- Works of 400d (Vikhlinin et al. 2009) and Allen group (Mantz et al. 2010) best current results

- In a like-for-like comparison, we expect an improvement in constraints by a factor ~2 (based on numbers) or more (redshift coverage)

- Mantz et al. find $\sigma(\Omega_M) = 0.04$, $\sigma(\sigma_8) = 0.05$, which matches this expectation quite well

XCS_{300}

Forecast: ΛCDM with other data

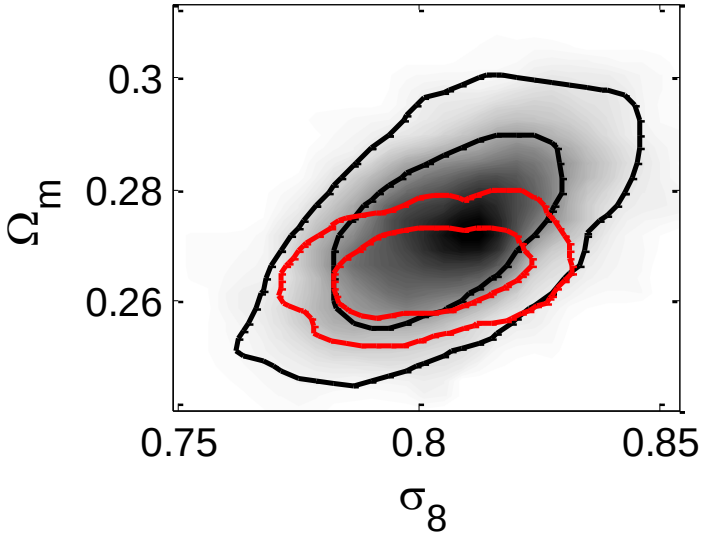


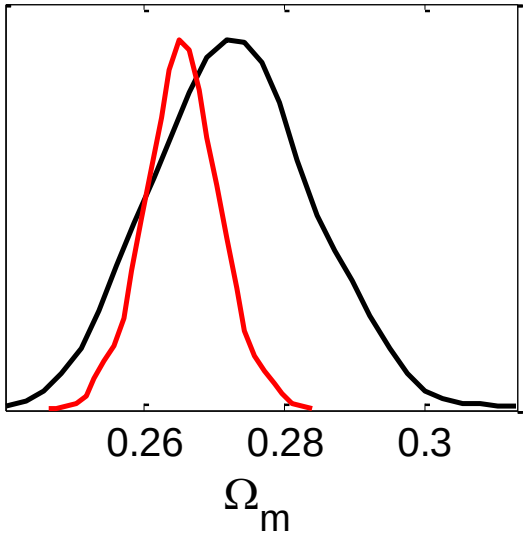
WMAP7+BAO+H_0

WMAP7+BAO+H_0+XCS_{300}

$\sigma_8 = 0.80 \pm 0.01$

$\Omega_M = 0.266 \pm 0.005$





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Fiducial model

$\Omega_M = 0.266$

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$h = 0.71$

$\sigma_8 = 0.801$

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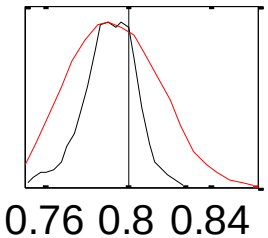
$\sigma(\alpha_{M\text{-}T}) = 15\%$

Varying

All $\alpha_{M\text{-}T}$

XCS_{300}

Forecast: Neutrino masses



Σm_ν/eV < 0.86 (0.95), 95% CL

$\sigma_8 = 0.80 \pm 0.01$, ± 0.02

$\Omega_M = 0.27 \pm 0.01$, ± 0.02

Fiducial model

$\Omega_M = 0.266$

$\Omega_b = 0.0449$

$\Sigma m_\nu = 0.0$ eV

$h = 0.71$

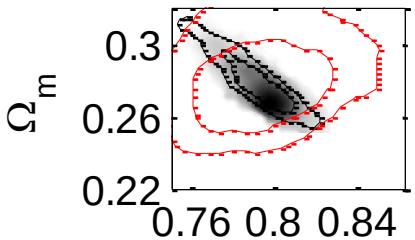
$\sigma_8 = 0.801$

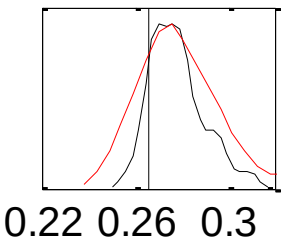
$n_S = 0.963$

$\sigma(\alpha_{M\text{-}T}) = 15\%$

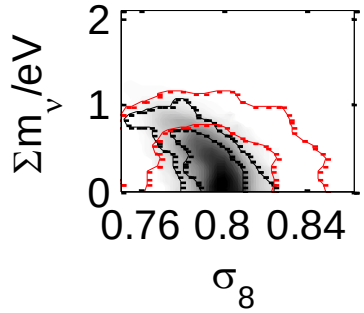
Fitting

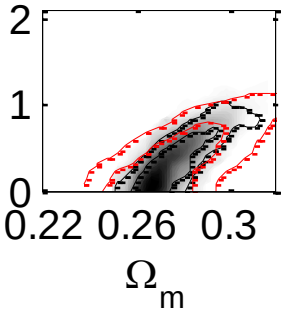
σ_8 Ω_M Σm_ν $\alpha_{M\text{-}T}$

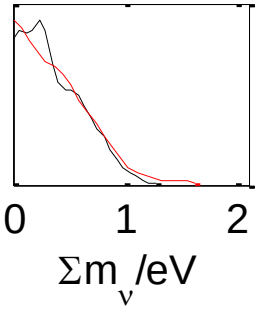




Work in progress, ultimately expect x2 improvement on CMB+clusters constraint



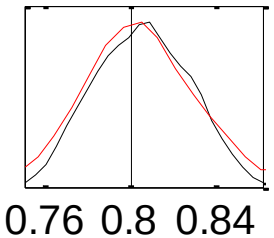




M.S. et al., in prep.

XCS_{300}

Forecast: Neutrino masses



Σm_ν/eV= 1.00 ± 0.40, ±0.43

σ_8 = 0.80 ± 0.02, ±0.03

Ω_M = 0.27 ± 0.02, ±0.03

Fiducial model

Ω_M = 0.266

Ω_b = 0.0449

Σm_ν = 1.0 eV

h = 0.71

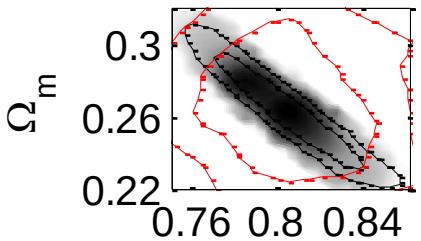
σ_8 = 0.801

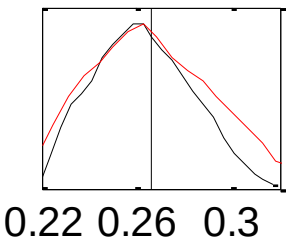
n_S = 0.963

$\sigma(\alpha_{M\text{-}T})$ = 15%

Fitting

σ_8 Ω_M Σm_ν $\alpha_{M\text{-}T}$





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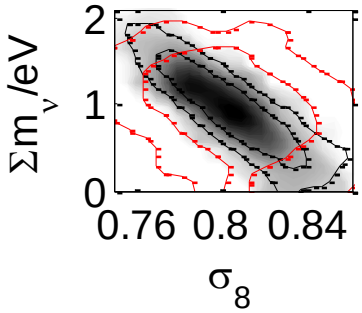
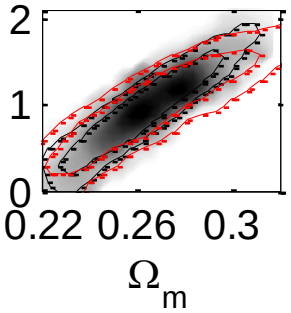
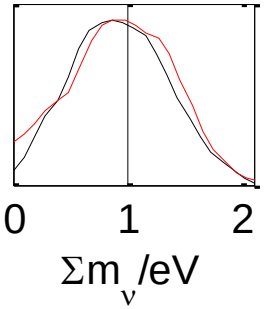






M.S. et al., in prep.

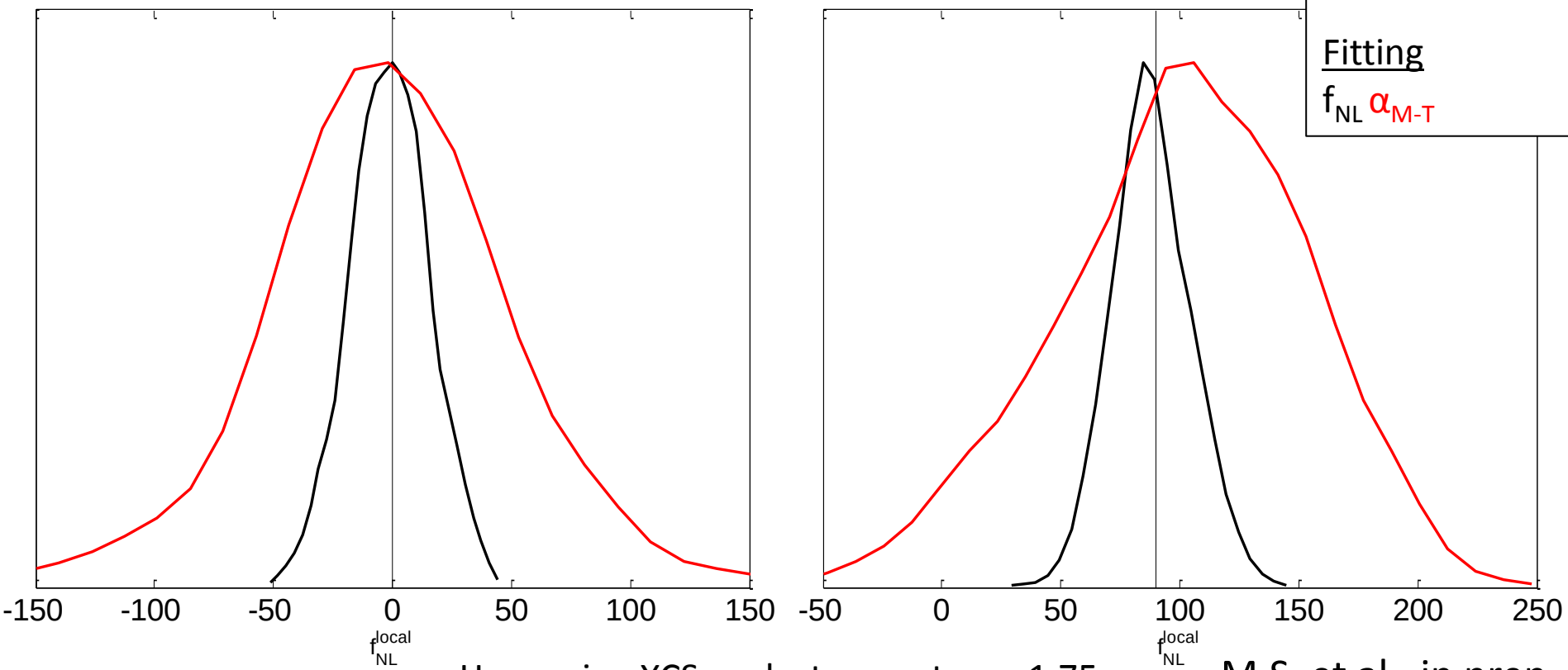
XCS_{300}

Forecast: Non-Gaussianity

Local f_{NL}: "Smoking gun" exclusion of single-field inflation

f_{NL} = 0 ± 16, ±51

f_{NL} = 90 ± 16, ±52



Fiducial model

$\Omega_M = 0.266$

$\Omega_b = 0.0449$

$h = 0.71$

$\sigma_8 = 0.801$

$n_S = 0.963$

$f_{NL} = 0$ and 90

$\sigma(\alpha_{M\text{-}T}) = 15\%$

Fitting

f_{NL} $\alpha_{M\text{-}T}$

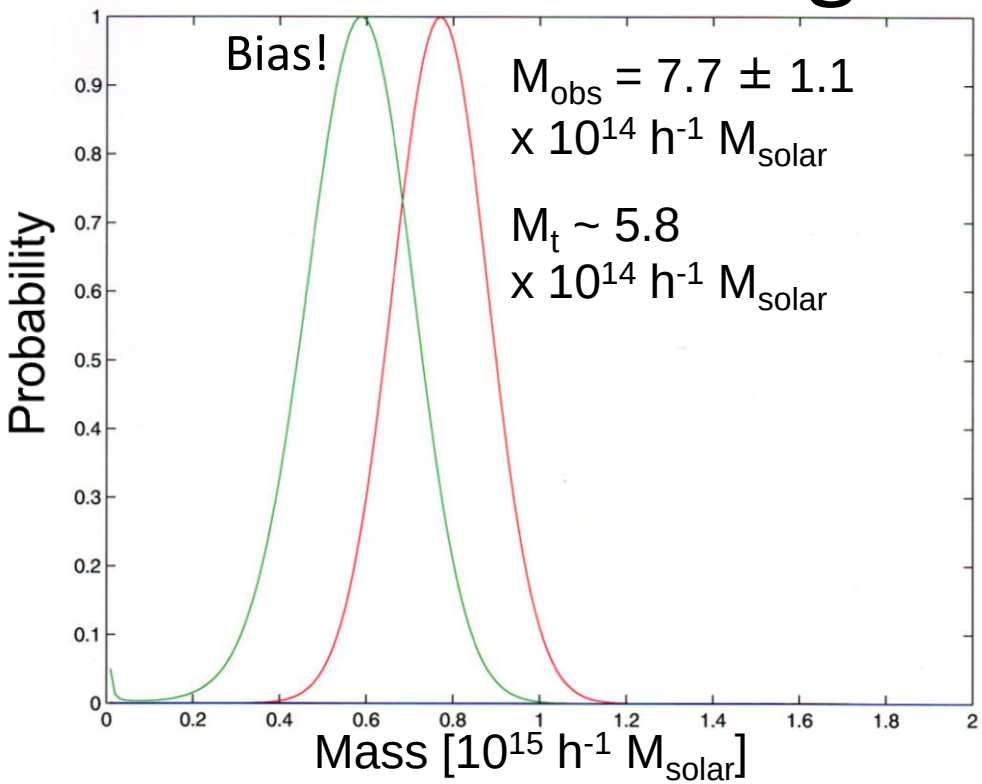
Here using XCS_{300} clusters up to z = 1.75

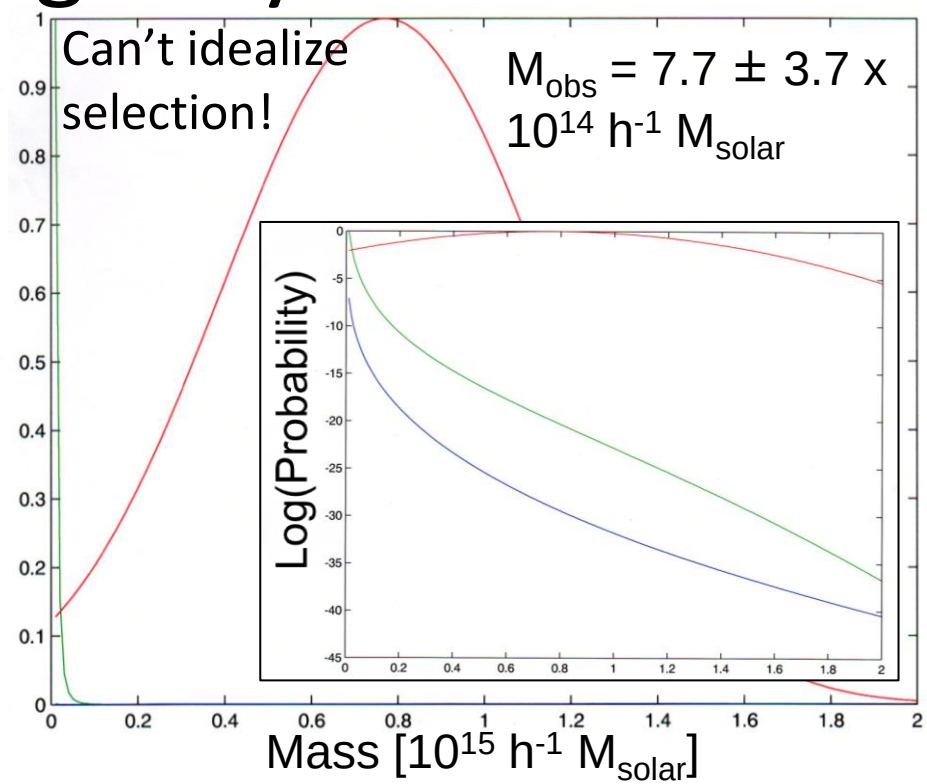
M.S. et al., in prep.

Complementarity depth-area: e.g. Oguri 2009, arXiv:0905.0920

Other work in preparation:

”The Bayes Diet”
for ”overweight” galaxy clusters





$$p(M_{\rm t}|M_{\rm obs}) = p(M_{\rm obs}|M_{\rm t})\,p(M_{\rm t})$$

M.S., in prep.

Important consideration for e.g. survey mass calibration

Conclusions

- The XMM Cluster Survey has released XCS-DR1, publicly available at www.xcs-home.org

- It is the largest homogeneous X-ray cluster sample to date, with 503 clusters, extending to high redshifts

- We find (in SDSS DR7 overlap) a distribution of clusters that agrees with a WMAP7 ΛCDM cosmology

Conclusions

- First cosmological constraints this year; next year considerable improvement [σ_8, Ω_m, w, m_ν, f_{NL}, γ, …]

- With WMAP7+BAO+H0:

Parameter	Worst-case(?) σ (w/ XCS syst.)
Ω_m	~ 0.005
σ_8	~ 0.01
Σm_ν*	< 0.5 eV

* but using e.g. full CMB covariance considerably better

Conclusions

- With strong priors on Ω_b, h, Ω_M & σ_8, n_S:

Parameter	Best-case σ	Worst-case(?) σ
f_{NL}	~ 15	~ 50

argument for e.g. XCS-XXL

- Detailed constraints and forecasts in prep.

- Claims of ”too massive” clusters often based on biased mass estimates; in my opinion most likely no tension with ΛCDM

Other avenues

- Similar work on e.g. XXL, eROSITA
- Modified-gravity models
- Quintessence models
- Public CosmoMC cluster module